

Thermo-Mechanical Modeling and Analysis for Turbopump Assemblies



Mike Platt
Concepts NREC

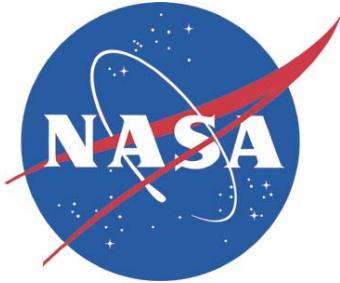
Matt Marsh
NASA MSFC

Outline

- Technical Need
- Project Goals
- Technical Approach
- Development Status
- Conclusion



Project Support



- NASA SBIR, through TD61
- Spin-off to IHPRPT
- Spin-off to industry



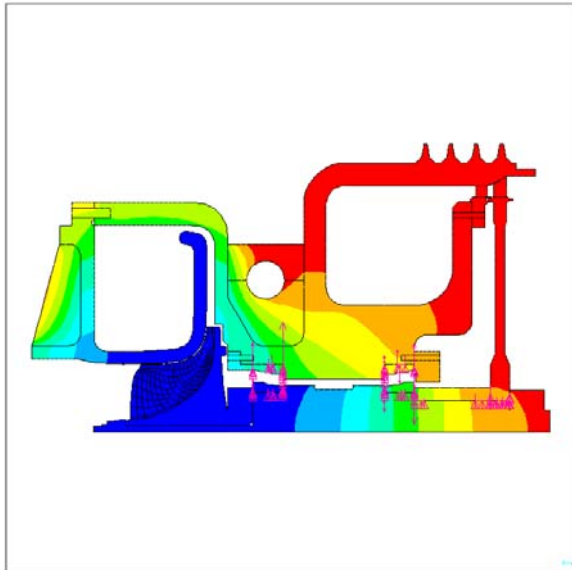
Technical Need

- Life, reliability, and cost are strongly impacted by steady and transient thermo-mechanical effects
- Design cycle can suffer big setbacks when working a transient stress / deflection issue
- Balance between objectives and constraints is always difficult
- Requires assembly-level analysis early in the design cycle



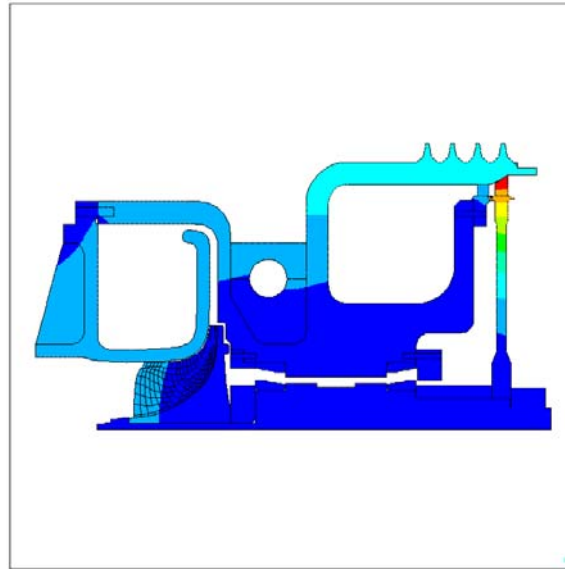
Technical Need – Operating Point

Temperature



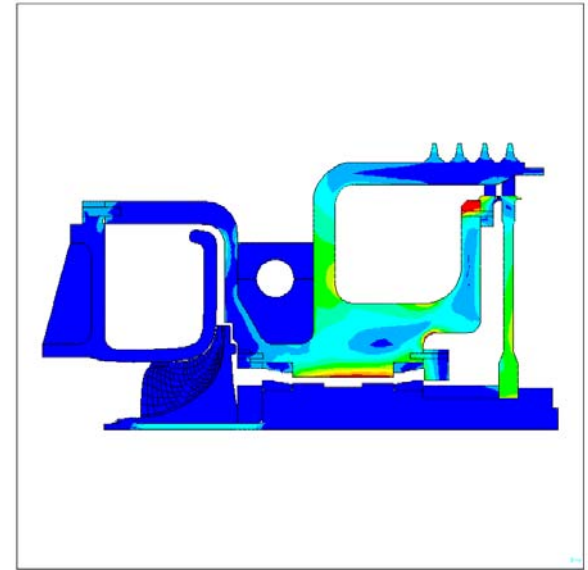
Absolute temperature limits and thermal gradient limitations

Displacement



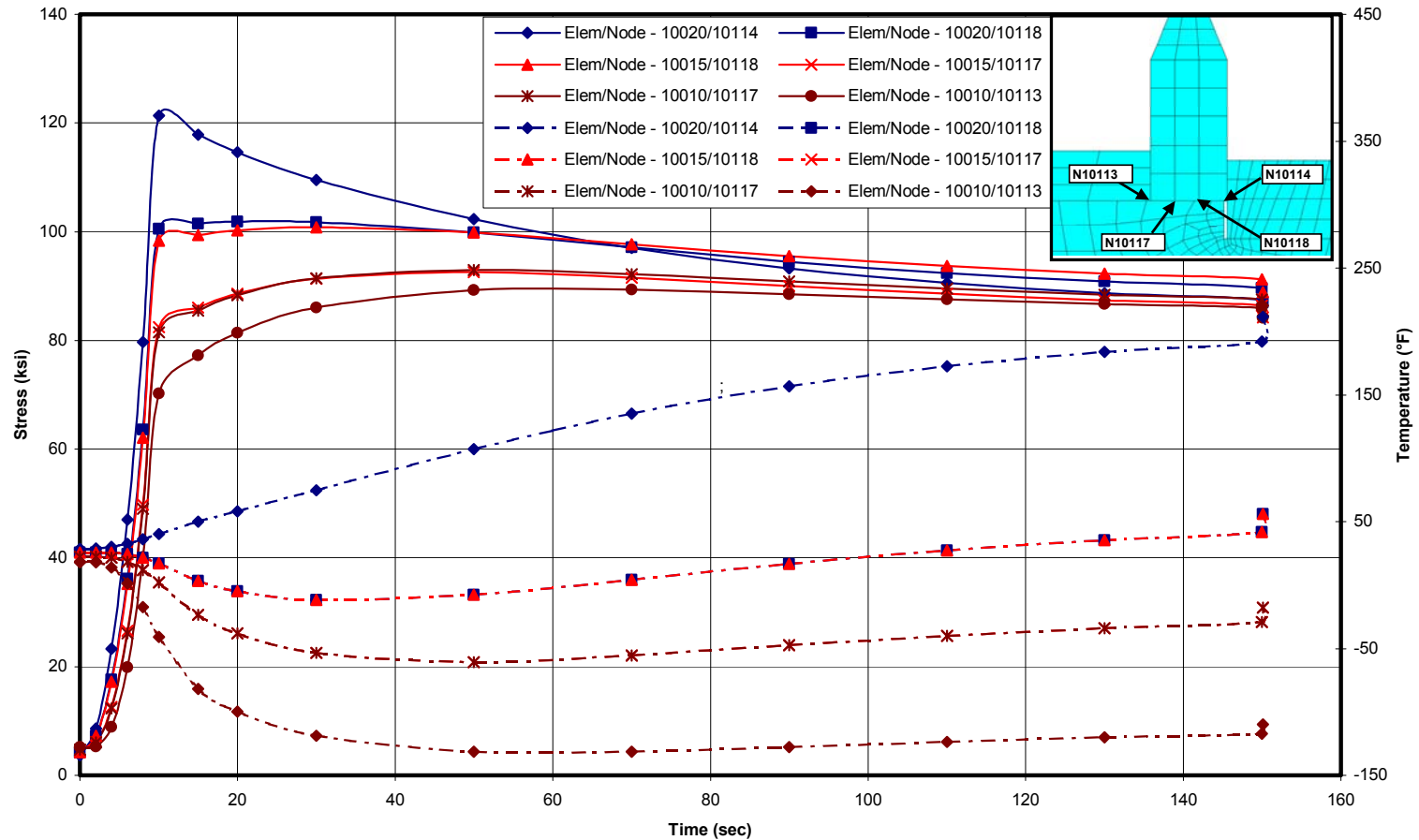
Critical clearances, fits, and gaps

Stress



Stress margins, LCF life, HCF margin, preloads

Technical Need - Transient



Project Goals

- Develop thermo-mechanical modeling software tools
 - Push thermo-mechanical modeling earlier in the design process
 - Reduce cost and risk of designs
 - Improve life and reliability of propulsion systems
- Integrate existing tools
 - Improve the design process
 - Open system for 3rd party software



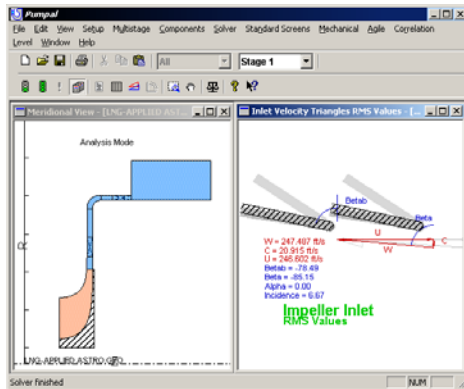
Technical Approach

- Design data and results flow from component analysis tools to the assembly model
- Software operates in a collaborative environment
 - Data-centric approach to multi-disciplinary analysis
 - XML provides flexible open data format
- Integrate with CAD data
- Integrate with multi-disciplinary optimizer

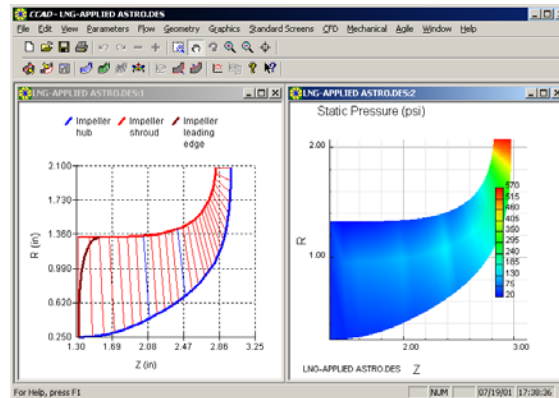


Data Flow to Assembly

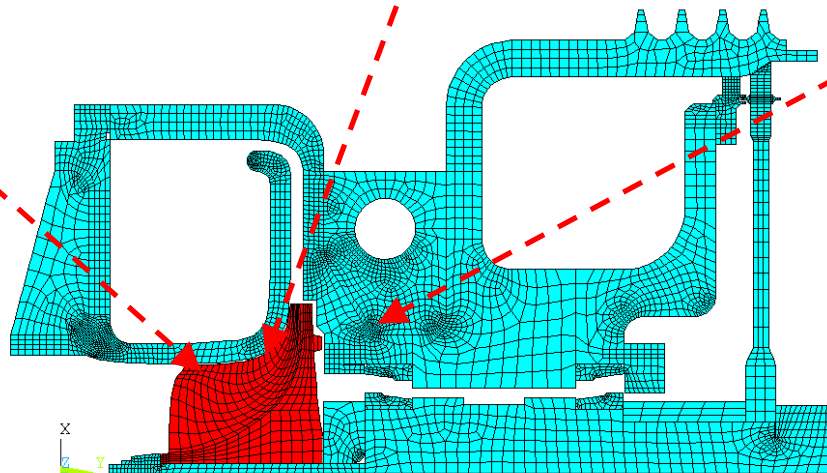
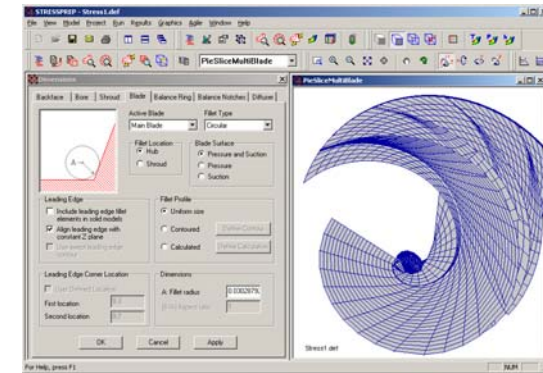
Meanline



3D Blading & CFD

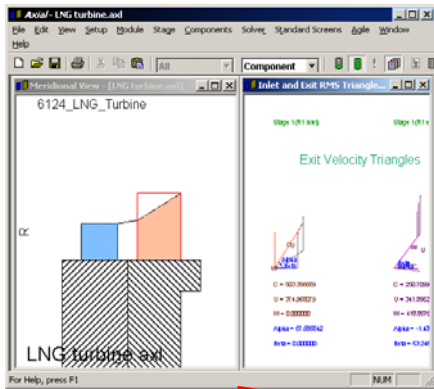


Stress & Vibration

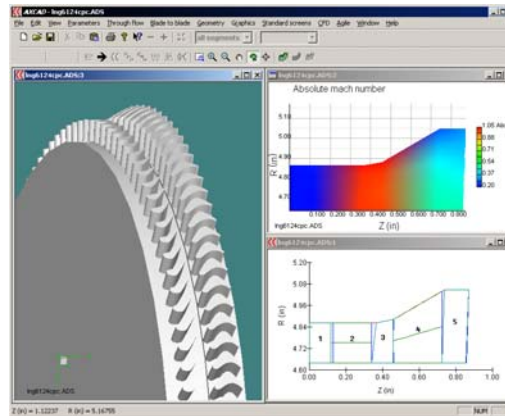


Data Flow to Assembly

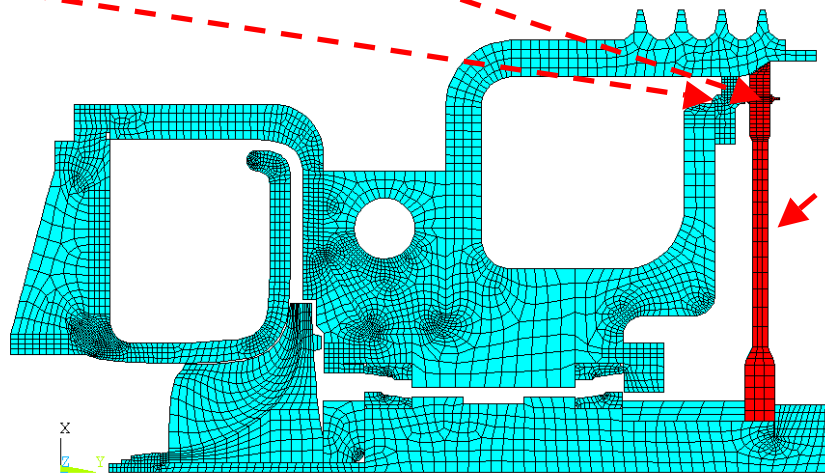
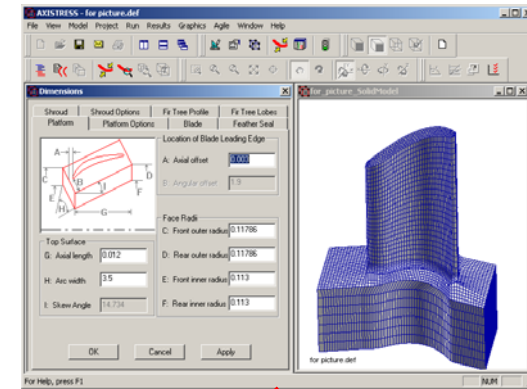
Meanline

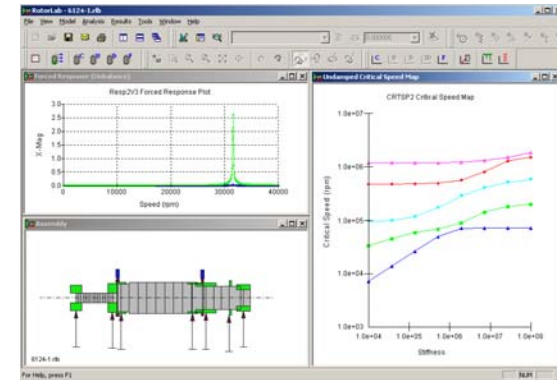
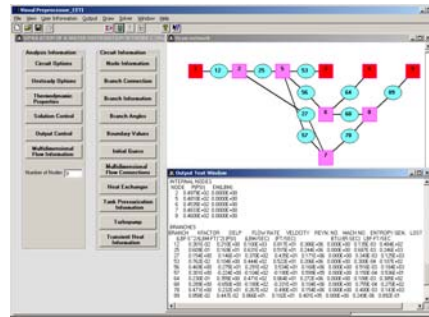
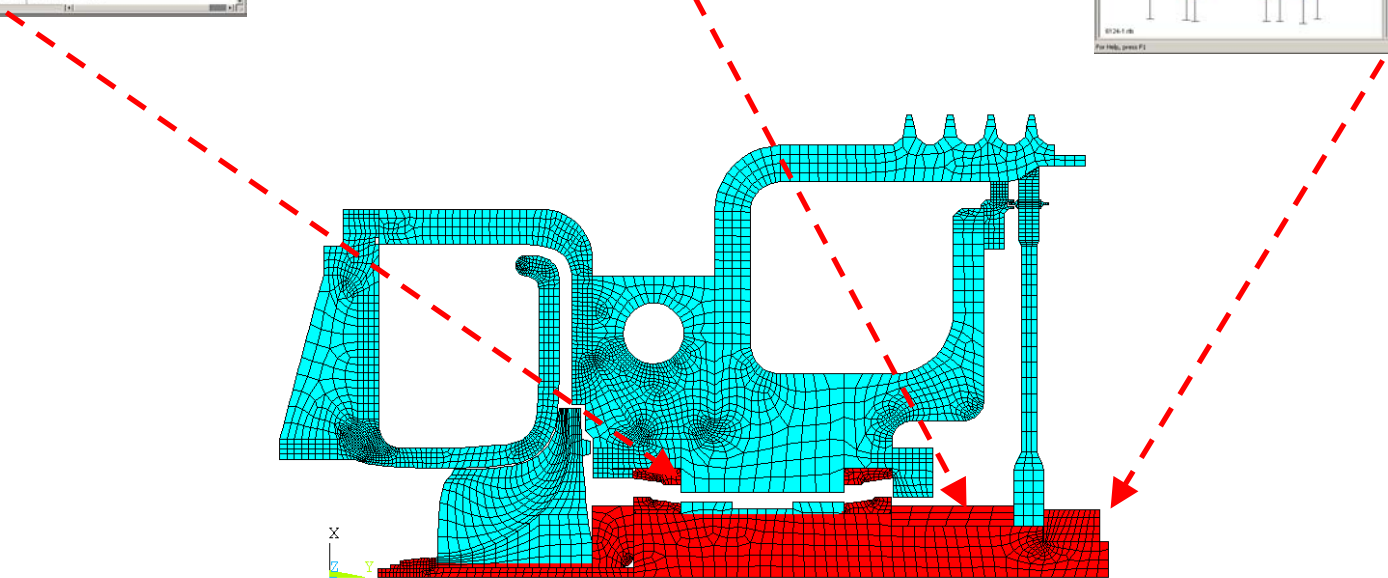


3D Blading & CFD

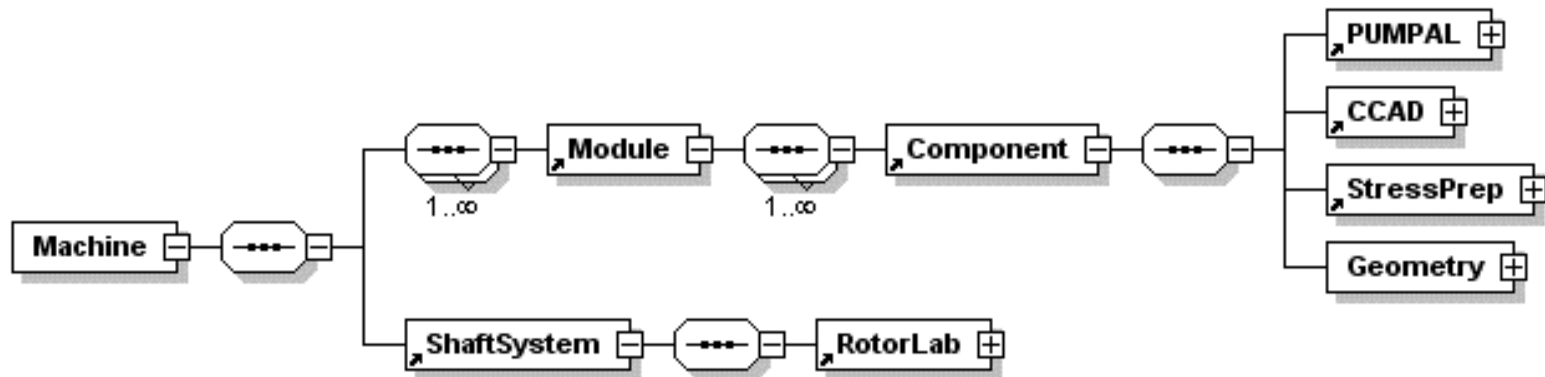


Stress & Vibration





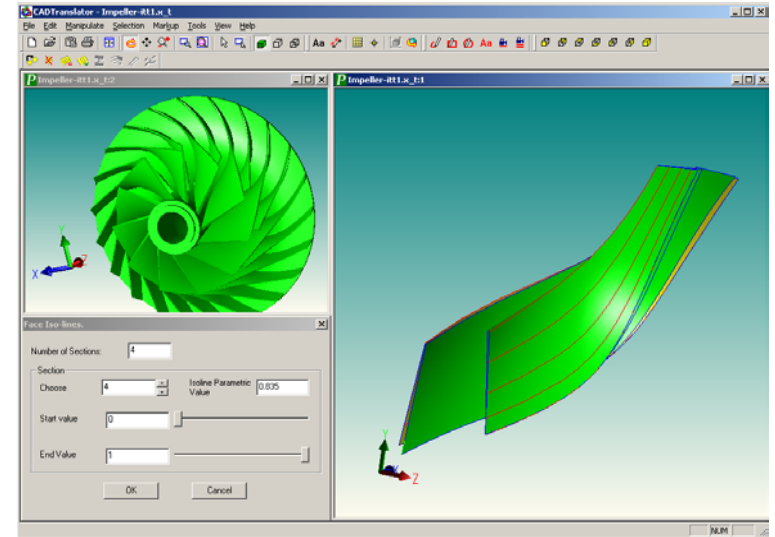
XML Data Set



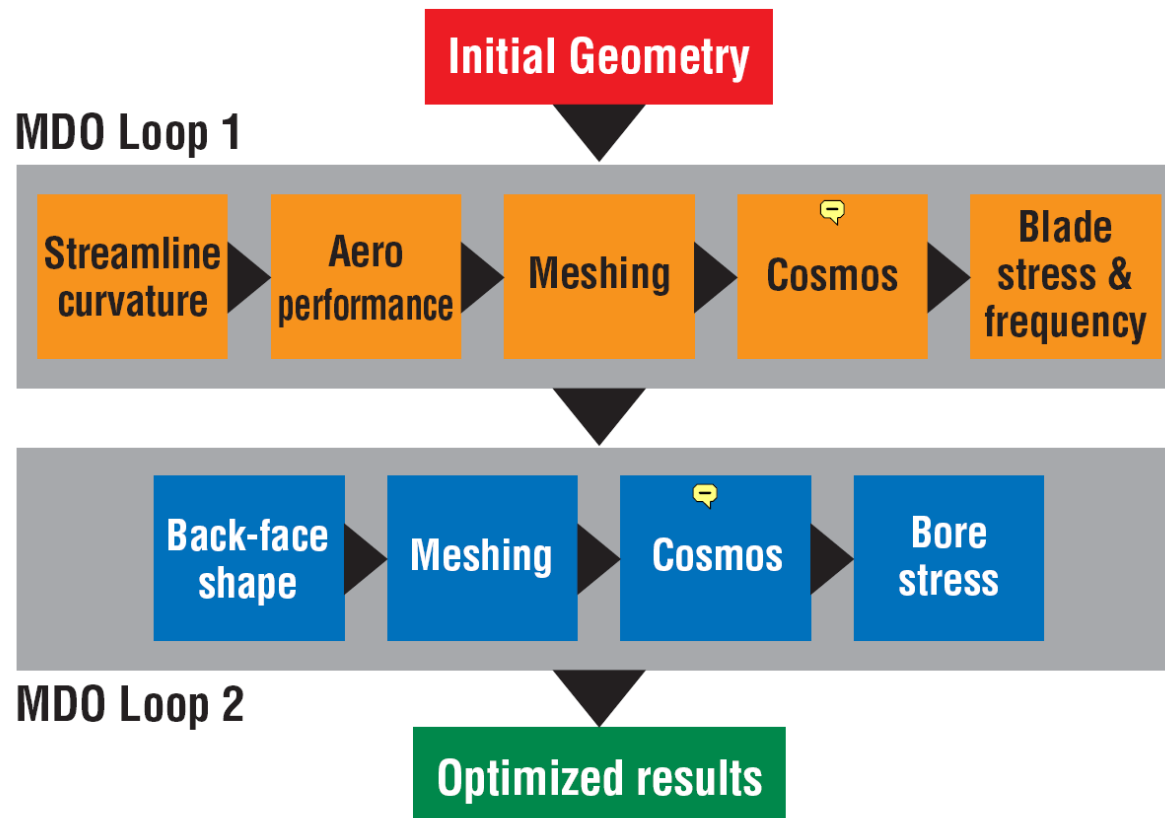
- Flexible, recursive data tree stores geometry, modeling parameters, and results from different disciplines
- XML provides robust open technology for data sharing
 - Format is self-descriptive and self-checking
 - Growing supply of XML tools for C++, Java, Perl, Python

CAD Integration

- Import/export of CAD files can be time consuming and error prone
- Individual tools can become segregated from design data flow
- Using Parasolid geometry kernel from EDS
Unigraphics:
 - Native files from Unigraphics
 - IGES for other CAD systems

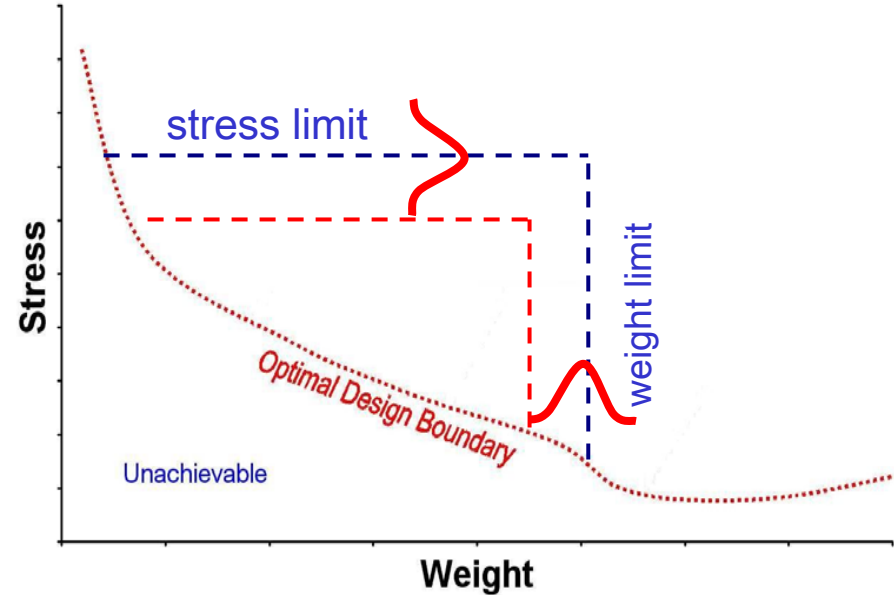


Multi-Disciplinary Optimization

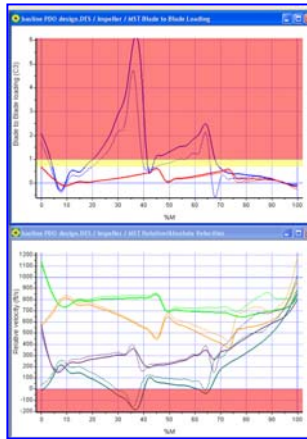


Incorporating Uncertainty

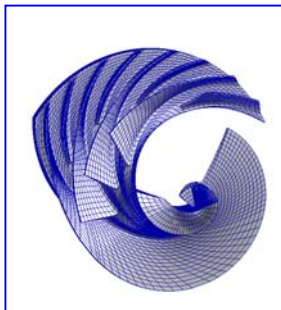
- Stress and weight limits both include uncertainty
 - Cannot design up to the limits
- Dimensions include uncertainty
 - Cannot only consider nominal part
- Monte Carlo simulations allow judicious use of design margin



Multi-Disciplinary Optimization



Quasi-3D
aero model



Solid FEA
model

Initial Geometry

MDO Loop 1

Streamline
curvature

Aero
performance

Meshing

Cosmos

Blade
stress &
frequency

Back-face
shape

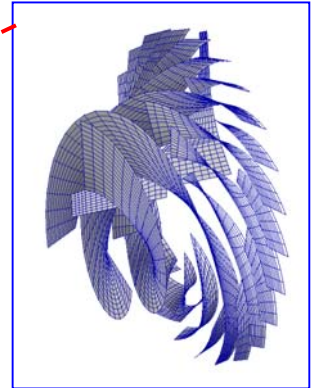
Meshing

Cosmos

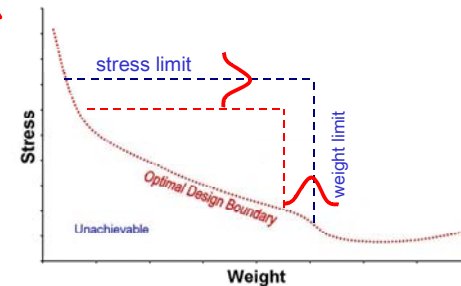
Bore
stress

MDO Loop 2

Optimized results



Quasi-3D
FEA model



Conclusion

- Software tool integration will push thermo-mechanical modeling upstream in the design process
- Open format data-centric approach has many advantages for sharing design data and results
- CAD integration provides a crucial link the the design process
- Software integration enables automated multi-disciplinary design trades